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# **Research: What It Says About 1 to 1 Learning**

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# Introduction

## Putting a Computer at the Fingertips of Every Student: The Growth of 1 to 1 Initiatives

Today 1 to 1 computing initiatives that seek to provide laptop computers and Internet access to students for use at home and school are expanding rapidly across the globe. These initiatives can help facilitate the transition in schools from occasional, supplemental use of computers for instruction to more frequent, integral use of technology across a multitude of settings.<sup>1</sup> Ubiquitous, 24/7 access makes it possible for students to access a wider array of resources to support their learning, to communicate with peers and their teachers, and to become fluent in their use of the technological tools of the 21st century workplace. Being able to take computers home further expands students' access, facilitates students keeping their work organized, and makes the computer a more "personal" device.<sup>2</sup>

The decreasing costs, combined with the lighter weight of laptops and increasing availability of wireless connectivity, are making 1 to 1 initiatives more feasible to implement on a broad scale. States such as Maine and Texas, for example, have invested in statewide initiatives to fund access to laptops for secondary school students. Large districts like Henrico County in Virginia and Cobb County in Georgia are providing laptops and digital content to all middle and high school students. Hundreds of independent, parochial, and individual public schools are also implementing demonstration and large-scale projects that provide 1 to 1, 24/7 access to computers and the Internet.

## Has Research Followed 1 to 1 Initiatives?

To date, research has not kept up with the rapid expansion of 1 to 1 initiatives or with their breadth. An earlier 2001 review of laptop initiatives that SRI International researchers conducted under contract with the U.S. Department of Education found just 19 studies that had analyzed outcomes. Researchers concluded at that time that there was too little research-based evidence to determine whether or not such programs were effective because the overall methodological quality of the studies was weak. As a result of that review and as part of an effort to discover what has been learned since then about 1 to 1 initiatives that rely on newer hardware and software, new questions arise:

- What new studies of 1 to 1 computing initiatives have been conducted, and what has been their focus?
- How are students and teachers using technology in initiatives?

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<sup>1</sup> Roschelle and Pea, 2002.

<sup>2</sup> Vahey and Crawford, 2002.

- What new information is available from studies about the conditions necessary for effective implementation?
- Have there been any rigorously-designed outcome studies published on the effectiveness of initiatives? If so, what outcomes have been measured?
- What research is still needed on 1 to 1 initiatives?

The present study, conducted under contract with Apple Computer, Inc., aims to analyze research-based evidence from research studies published between 2001 and 2005 and to identify what is known and not yet known about:

- The effects of 1 to 1 computing initiatives on students
- How students use laptops and wireless connectivity
- What teaching looks like in 1 to 1 classrooms

### **Definitions Used in this Synthesis**

#### **Outcome studies**

*Studies that use objective measures of program impact and that rely on treatment-comparison group designs. Such studies yield research-based evidence about the effectiveness of 1 to 1 initiatives.*

#### **Research-based evidence**

*Data gathered from rigorously-designed outcome studies. The strength of research-based evidence depends upon the strength of the research design, not how big the reported effects are.*

#### **Implementation studies**

*Studies that use surveys, interviews, or case studies to describe how 1 to 1 programs unfold and how program stakeholders such as parents, teachers, administrators, and students perceive them.*

The results of this research synthesis are intended to strengthen Apple Computer's support of 1 to 1 initiatives in four key ways. First, the research synthesis is intended to clarify which claims about the effects of 1 to 1 initiatives are supported by rigorously-designed research studies. Second, the synthesis is intended to glean lessons from implementation studies about how 1 to 1 initiatives unfold under different kinds of circumstances. Third, the synthesis is aimed at identifying potential targets for classroom-based assessment that teachers can use to document transformations in instruction and improvements in student learning. Fourth, the synthesis can identify gaps in the knowledge base, which might be addressed in research and evaluation studies being conducted in conjunction with 1 to 1 initiatives that Apple supports.

In the following sections, we describe the key findings from the research synthesis of findings from 30 separate studies of 1 to 1 initiatives. First, we review the goals and scale of different initiatives in the review. Next, we look at particular design features and factors that might most strongly influence teachers and overall implementation. We then focus on the effects shown by the limited number of rigorously designed studies in the field and follow with an analysis of the untapped potential of most 1 to 1 studies to date.

We follow the research review with recommendations for evaluation researchers who are studying 1 to 1 initiatives. These recommendations are aimed at improving the implementation data available from studies and enhancing the quality of research-based evidence available about the effects of providing laptops and wireless connectivity in such initiatives.

The details of our approach to finding, selecting, and analyzing studies included in the synthesis appear in Appendix A of this report. The studies included in the synthesis are identified in Appendix B.

### **Goals of 1 to 1 Computing Initiatives Include:**

- **Academic achievement:**  
*Improving academic achievement through use of technology*
- **Equity:** *Increasing equity of access to digital resources*
- **Economic development:**  
*Increasing economic competitiveness by preparing students for today's workplaces*
- **Enhancing teaching:**  
*Transforming the quality of instruction*

## **The Goals and Scale of 1 to 1 Initiatives Vary Widely**

Beyond providing laptop and Internet access to students, the goals for the 1 to 1 initiatives included in the research synthesis tend to focus on one or more of four outcomes.<sup>3</sup> For some initiatives, the primary focus is on improving *academic achievement* with the use of technology. For others, the goal is increasing *equity of access* to digital resources and reducing the digital divide. For still other initiatives, including the statewide initiative in Maine, the goal is increasing the *economic competitiveness* of the region by preparing its students more effectively for today's technology-saturated workplaces. Finally, some initiatives introduce ubiquitous access to computers to seek to *effect a transformation in the quality of instruction*. Many of the initiatives that are focused on transforming teaching aim specifically to make instruction more "student-centered," that is, more differentiated, problem- or project-based, and demanding of higher-order thinking skills.

The initiatives also vary widely in their scale. Some initiatives are providing laptop computers with wireless Internet access to tens of thousands of students across a district or entire state. In still others, schools are experimenting classroom by classroom with introducing laptop computers into instruction. The challenges posed by scale are no doubt different from those posed by small pilot projects. In addition to coordinating professional development and technical support for larger numbers of teachers, large-scale initiatives must address the challenge of ensuring that programs address local teachers' needs and individual schools' own goals for improving teaching and learning. Smaller-scale initiatives often face challenges in finding enough funding to support teachers and the technology. Coordinating instruction with laptops when not all students in a school have laptops is an additional challenge.

## **Trends in Students' Use of Laptops Indicates Early Stage of Technology Adoption**

A number of implementation studies have examined how students are using laptops in their classrooms and at home. Across a wide range of studies, students use laptops primarily for writing, taking notes, completing homework assignments, keeping organized, communicating with peers and their teachers, and researching topics on the Internet. For these tasks, they are using word-processing software, web browsers, email, and chat. Use of software programs designed to teach basic skills appears to be less common, observed in only four of the programs studied by researchers whose work is included in this synthesis.<sup>4</sup>

<sup>3</sup> Lemke and Martin, 2003a; Lemke and Martin, 2003b; Lemke and Martin, 2003c; Lemke and Martin, 2003d; Zucker, 2004.

<sup>4</sup> Daitzman, 2003; Davis, Garas, Hopstock, Kellum, and Stephenson, 2005; Mitchell Institute, 2004; Warschauer, Grant, Real, and Rousseau, 2004; Zucker and McGhee, 2005.

### **Lessons Learned from Research on Scaling of Educational Technology Innovations**

*In 2003, a group of educational technology researchers, policymakers, and practitioners gathered at the Harvard Graduate School of Education to discuss what factors are critical to scaling up success with technology-supported innovations in education.*

*Researchers Chris Dede and James P. Honan summarized the themes that emerged from the conference in an edited volume, *Scaling Up Success: Lessons from Technology-based Educational Improvement* (Jossey-Bass)<sup>5</sup>:*

- *Innovations must adapt to the changing contexts in which they are implemented.*
- *Leaders of innovations must be able to adapt to changes in policies and funding levels.*
- *Innovations require a broad base of support from those who are implementing them.*
- *People working to ensure broad-scale adoption of the innovation must build capacity for implementation through partnerships and professional development.*
- *Leaders of innovations require ongoing data to judge the success of the innovation and make improvements to innovation designs.*

Most of these uses appear to reflect the fact that the observed students' teachers are in an "adaptation" stage of technology adoption.<sup>6</sup> In other words, they are adapting traditional teaching strategies to incorporate more adult productivity tools and are having students work independently and in small groups, but they have not yet begun to widely implement more student-centered strategies for instruction, such as project-based learning. Those students who do engage in more extended projects typically use design and multimedia tools, including presentation software and software for making and editing digital images and movies.<sup>7</sup> Researchers presented several compelling examples of students' digital products, and some noted that these were particularly compelling to parents and adults in the school community.<sup>8</sup>

### **Teachers' Attitudes and Beliefs Affect Implementation and Program Success**

Case studies of teachers in laptop programs have shown that teachers' beliefs about students, the potential role of technology in learning, and the availability of high-quality digital content influence the degree to which they use laptops with students.<sup>9</sup> Although overall few studies on 1 to 1 computing initiatives have presented research-based evidence that determines the true effectiveness of the programs, there is evidence that particular program designs and factors affecting teacher attitudes and beliefs influence a program's implementation and success. Teachers who believe that students are capable of completing complex assignments on their own or in collaboration with peers may be more likely to assign extended projects that require laptop use and to allow students to choose the topics for their own research projects. Teachers who view technology as a tool with a wide variety of potential applications are more likely to use laptops often with students.<sup>10</sup> Third, those teachers who believe that there are adequate software and Internet-based resources available to help teach their particular content area may use laptops with students more often than teachers who believe that there are simply not enough high-quality materials available.<sup>11</sup>

Particular design features may influence teachers' beliefs in such a way as to make them likely to use laptops in conjunction with student-centered modes of instruction. Project Hiller, a within-school laptop program for high school students, required its teachers to engage in two extended projects with students and to mentor two or three

<sup>5</sup> Dede and Honan, 2005.

<sup>6</sup> Sandholtz, Ringstaff, and Dwyer, 1997.

<sup>7</sup> Davies, 2004; Davis, Garas, Hopstock, Kellum, and Stephenson, 2005; Light, McDermott, and Honey, 2002; Mitchell Institute, 2004; Newhouse and Rennie, 2001; Stevenson, 2002; Warschauer, Grant, Real, and Rousseau, 2004; Windschitl and Sahl, 2002.

<sup>8</sup> Light, McDermott, and Honey, 2002.

<sup>9</sup> Windschitl and Sahl, 2002.

<sup>10</sup> Jailliet, 2004; Windschitl and Sahl, 2002.

<sup>11</sup> Lane, 2003; Trimmel and Bachmann, 2004.

*"[T]he kids in Hiller are more academically inclined, you treat them as gifted and they act as expected and beyond. The students have surpassed my expectations and their commitment has impressed me."*

Teacher from Project Hiller, in Light, McDermott, and Honey (2001), p. 27.

student-driven projects in the school. In their projects, Project Hiller students took on significant and visible roles within the school, including helping teachers with planning lessons that used technology, developing multimedia materials for departmental projects, mentoring younger peers, and producing a newsletter. Many of the teachers reported that their expectations of what their students could do changed after seeing how skilled students were with using multimedia tools. The teachers reported that they then began assigning more complex and challenging work to students.

The researchers who studied Project Hiller found that the number of teachers who reported doing long-term projects (at least once a year or more) increased from 85% to 95% over the course of the project, as did the number of teachers who use journaling with their students, which rose from 58% to 68%.<sup>12</sup> Analysis of observational data and interviews with Project Hiller teachers, students, and coordinators revealed an increase in the occurrence and quality of informal, project-based and small group interactions between teachers and students participating in the program.<sup>13</sup>

## **Professional Development and Technical Support Are Critical for Implementation**

Several of the implementation studies examined what teachers, students, and administrators believed were critical factors in supporting implementation of laptop programs. In addition, some researchers conducted observations in programs that led them to draw conclusions about what features of programs support or hinder implementation. These studies can provide valuable information for understanding implementation, even though research-based evidence that such factors lead to better student outcomes does not yet exist.

Formal professional development has been a critical component of many large-scale and smaller laptop programs. Teacher workshops often focus on providing teachers with skills they need to use the technology themselves, but many also focus on helping teachers integrate technology into their instruction.<sup>14</sup> In Maine, content specialists have also been assigned to help teachers with finding digital resources and integrating technology into specific content areas.<sup>15</sup> In addition, some programs have assigned staff (either internal to the school or external) to help teachers on an as-needed basis with technology integration.<sup>16</sup> A third form of professional development, informal help from colleagues within the school, may be especially important to ensuring implementation success. A number of researchers reported that they observed teachers helping each other

<sup>12</sup> Light, McDermott, and Honey, 2002.

<sup>13</sup> *Ibid.*

<sup>14</sup> Davies, 2004; Dinnocenti, 2002; Fairman, 2004; Harris and Smith, 2004; Lane, 2003; Lowther, Ross, and Morrison, 2001.

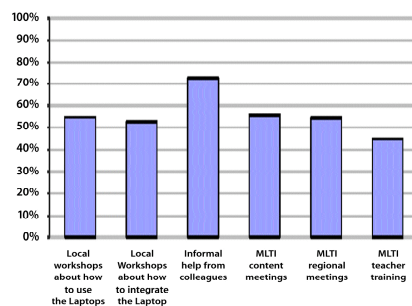
<sup>15</sup> Silvernail and Harris, 2003.

<sup>16</sup> Dinnocenti, 2002; Davies, 2004; Fairman, 2004; Light, McDermott, and Honey, 2002.

### **Teachers' Perceptions of Professional Development in the MLTI**

*The Maine Learning Technology Initiative (MLTI) has employed a variety of strategies to help teachers learn to integrate laptops into their teaching and use them to plan for instruction in their content areas. As the graph below shows, the majority of teachers view each of these as effective. By far, however, teachers perceived informal support from colleagues as the most effective form of professional development.*

**Percentage of Teachers who responded "Effective" or "Very Effective" when asked to rate the following Professional Development activities:**



Graph Source: Silvernail, D., & Lane, D. M. M. (2004). *The impact of Maine's one-to-one laptop program on middle school teachers and students: Phase one summary evidence*. Portland, ME: Maine Education Policy Research Institute, University of Southern Maine, p. 11.

*"We have a kid who isn't a top student. He doesn't get all A's, but he knows a lot about computers. The other teacher on my team is not very good with technology, and she goes to him and he loves that. It's been a way for him to stand out and make a difference."*

Teacher in the MLTI, quoted in Fairman (2004), p. 8.

with technology problems or engaging in joint curriculum planning, and some have even reported that teachers prefer this form of professional development above others.<sup>17</sup>

Some of the professional development that is targeted to help teachers become more "student-centered" in their teaching has been especially effective in transforming instruction in laptop classrooms. A good example of such a program is the iNtegrating Technology for inQuiry (NTeQ) model,<sup>18</sup> which helps teachers develop extended problems and projects that use real-world resources, student collaboration, and computer tools to reach solutions or create final products. The model calls for a full 10 days of professional development for teachers, plus follow-up during the year. Comparison group studies of teachers who were provided the NTeQ program and then assigned either to a laptop classroom or a non-laptop classroom suggest that laptops can facilitate more use of project-based learning and cooperative grouping strategies.<sup>19</sup>

Readily available technical support also appears to be important for laptop programs to succeed. Programs in which teachers report a high degree of reliability for laptops often have both within-building technical support staff devoted to helping with the program and ready access to outside vendors for major problems.<sup>20</sup> Ensuring that all students' laptops are working makes it less likely that teachers will have to develop two sets of assignments—one for students with laptops and another for students without laptops.<sup>21</sup> Being able to count on the reliability of the school's wireless network is also critical, since students are often using their laptops to access resources available on the web.<sup>22</sup>

Students have played an important role in providing the first line of technical support in several laptop programs. In Maine, for example, student "iTeams" exist in many schools to help troubleshoot routine problems with machines.<sup>23</sup> In addition, teachers in Maine report that they often turn to students for help with technical problems when they arise in class.<sup>24</sup> In other, smaller scale laptop programs, students play a similar role in providing technical support, both informally and formally as part of the program design.<sup>25</sup>

<sup>17</sup> Davis, Garas, Hopstock, Kellum, and Stephenson, 2005; Gaynor and Fraser, 2003; Lane, 2003; Silvernail and Harris, 2003; Windschitl and Sahl, 2002.

<sup>18</sup> Morrison, Lowther, and DeMuelle, 1999.

<sup>19</sup> Lowther, Ross, and Morrison, 2001.

<sup>20</sup> Hill and Reeves, 2004.

<sup>21</sup> Davis, Garas, Hopstock, Kellum, and Stephenson, 2005; Gaynor and Fraser, 2003; Zucker and McGhee, 2005.

<sup>22</sup> Hill and Reeves, 2004; Lane, 2003; Light, McDermott, and Honey, 2002.

<sup>23</sup> Silvernail and Harris, 2003; Silvernail and Lane, 2004.

<sup>24</sup> Fairman, 2004.

<sup>25</sup> Dinnocenti, 2002; Light, McDermott, and Honey, 2002.



## Studies with More Rigorous Designs Show Positive Effects

The strongest available research-based evidence for the positive effects of laptop programs comes from researchers who analyzed differences between laptop program students and comparison group students using objective tests of some kind. Notably, researchers obtained these results relatively early in the implementation of the programs (within the first three years of the program). Positive effects from these studies include increased technology use, increased technology literacy, and improved writing.

Russell, Bebell, and Higgins<sup>26</sup> compared the advantages for different student to computer ratios in classrooms. In a single public school, the school assigned different numbers of laptops to upper elementary grade classrooms to achieve either 4:1, 2:1, or 1:1 student: computer ratios. The researchers then observed classrooms and studied how students used computers in the classes and how teachers organized their instruction. The 1:1 classrooms provided several advantages over the 2:1 and 4:1 classrooms. In 1:1 classrooms, students used computers more across the curriculum and used them at home for academic purposes. In addition, their images of what is required for writing tasks nearly always included computers. In 1:1 classrooms, instruction was different as well; there was less large-group instruction than in 2:1 and 4:1 classrooms. Research-based evidence from six other comparison group studies that used post-test only designs also showed that students in laptop programs use computers more often and for a wider array of purposes than do students with less ubiquitous access to computers.<sup>27</sup>

The best research-based evidence for the effects of laptop programs on technology literacy comes from a study conducted by Schaumburg.<sup>28</sup> She studied the effects of a program that provided laptops to students in a high school in Germany. She found that the laptop students made greater gains than did comparison group students on a researcher-developed test of their knowledge of hardware and the laptop's operating system, common productivity tools, skill in using the Internet, and knowledge of basic computer security. Other comparison group studies with post-test only designs reported greater levels of technology literacy among students in laptop programs, using judgments made by researchers on the basis of structured observations of their skill in using computers and the Internet.<sup>29</sup>

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<sup>26</sup> Russell, Bebell, and Higgins, 2004.

<sup>27</sup> Jaillet, 2004; Light, McDermott, and Honey, 2002; Lowther and Ross, 2003; Stevenson, 2002; Trimmel and Bachmann, 2004.

<sup>28</sup> Schaumburg, 2001.

<sup>29</sup> Lowther and Ross, 2003; Lowther, Ross, and Morrison, 2001.

### Challenges to Conducting Rigorous Research

*There are many conditions that make it difficult to conduct studies that meet the criteria of being rigorously designed. Some of those conditions are especially common among 1 to 1 initiatives:*

- *When initiative goals do not map onto easily measured constructs (for example, “increased economic competitiveness”), evaluators may not be able to identify or construct suitable outcome measures.*
- *Constructing new outcome measures closely aligned to goals is costly, and such measures may be perceived as less credible by some than are existing measures such as attendance, discipline, and test scores.*
- *If the initiative begins quickly, evaluators may not have time to collect baseline data.*
- *If the initiative covers an entire state or district, it may be difficult to identify a suitable comparison group.*
- *Educators may not consent either to random assignment or to being in a comparison group.*

We identified four separate studies that reported positive effects of laptop programs on students’ writing skills.<sup>30</sup> However, none of these studies used a pretest to determine whether students had actually improved their writing skills over the course of the study. Therefore, although several studies reported positive effects, the research-based evidence that laptop programs can improve writing is somewhat less strong than the research-based evidence of effects on technology use and technology literacy.

### Challenges to Conducting Rigorous Research

The more rigorously designed studies do show positive effects, and some case studies and implementation studies point to design features and factors that may influence teachers to use laptops in their more student-centered modes of instruction. Overall, however, the largest impediment to providing policymakers and program developers with how well 1 to 1 initiatives are working is the design of the studies themselves. In our review, we found few studies that presented research-based evidence of any kind that could help determine how effective 1 to 1 initiatives really are. Only a single study used an experimental design to randomly assign teachers or students to treatment and comparison groups. That study used non-standard statistical techniques to analyze the data and did not identify whether classrooms or students was the unit of analysis; it was therefore not included in our synthesis.<sup>31</sup> Just three studies used a quasi-experimental design, in which pretest and post-test data from both treatment and comparison groups were assigned. None of these studies matched treatment and comparison groups, although all three used statistical techniques to analyze or control for initial differences in pre-program scores on the outcome measures. The remainder of the studies we obtained and reviewed as potential outcome studies did not meet the design criteria for possible inclusion, despite the fact that some of these articles described their goals as measuring the “impacts” of laptop programs on teaching and learning.<sup>32</sup> Some of these studies are included in the synthesis as implementation studies, since they did employ systematic approaches to analyzing how teachers and students used laptops in the different programs (see Appendix A for inclusion criteria).

Although reading and mathematics were a key focus of many laptop initiatives, only one of the studies we reviewed had examined effects on student achievement on state tests in those core subject areas. That study found that students in laptop classrooms made greater gains than did students in comparison classrooms on state tests.<sup>33</sup> Although the treatment and comparison group students did not have

<sup>30</sup> Gulek and Demirtas, 2005; Light, McDermott, and Honey, 2002; Lowther and Ross, 2003; Lowther, Ross, and Morrison, 2001.

<sup>31</sup> McTeer, 2004.

<sup>32</sup> Clark, 2003; Gravelle, 2003; Lane, 2003; Muir, Knezek, and Christensen, 2004; Sargent, 2003; Silvernail and Lane, 2004.

<sup>33</sup> Gulek and Demirtas, 2005.

different test scores at the beginning of the study, the fact that students and teachers were not randomly assigned means that there is some risk that the teachers who volunteered to participate in the laptop program were somehow different from those who were not in the program or that the students differed on some other set of important characteristics. Furthermore, the researchers did not examine how or for what purpose students in this program used their laptops. The absence of data on implementation makes it difficult to know whether laptop computers or some other aspect of the intervention caused students' test scores to increase.

In the past few years, policymakers have emphasized the need for more rigorous, "scientifically-based" research in education.<sup>34</sup> However, no studies have yet been completed and published that have been influenced by the new emphasis on experimental or quasi-experimental design.<sup>35</sup> The finding that few rigorous studies of laptop programs have been conducted between 2001 and 2005 is consistent with SRI's earlier review of laptop programs completed in 2001.<sup>36</sup> In that synthesis, we found just a few studies that met the same criteria for inclusion as outcome studies. At the time, that finding was not surprising, because until recently there have been few experimental studies in education.<sup>37</sup> In our synthesis, the only potential evidence of the influence of policymakers' new emphasis on more rigorous, scientifically-based research is reflected in the fact that several studies included in our synthesis had been published in peer reviewed journals<sup>38</sup>, a central criterion in judging the merit of research studies. In our earlier synthesis, there were no studies published in peer-reviewed journals.

The finding that there is little implementation data from well-designed outcome studies is consistent with the earlier SRI synthesis of laptop programs. Most of the researchers whose studies we reviewed chose to focus on measuring implementation or outcomes, but not both. Implementation data is critical, because evaluation studies of educational innovations often find that teachers do not always implement programs as intended by designers.<sup>39</sup> If effects of a program are positive, implementation data helps program designers understand what features are critical to success; and if effects are negative, the data can help explain failure.<sup>40</sup> The fact that there are few studies of laptop programs that measured both outcomes and implementation means that there is a weak research-based evidence base for deciding what the critical components of laptop programs really are.

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<sup>34</sup> National Research Council, 2002.

<sup>35</sup> An experimental study funded by the U.S. Department of Education is now underway in Texas. Results of that study are not yet available.

<sup>36</sup> Penuel, Kim, Michalchik, Lewis, Means, Murphy, Korbak, Whaley, and Allen, 2001.

<sup>37</sup> Cook, 2002.

<sup>38</sup> Gulek and Demirtas, 2005; Jaillet, 2004; Newhouse, 2001; Newhouse and Rennie, 2001; Trimmel and Bachmann, 2004; Warschauer, Grant, Real, and Rousseau, 2004; Windschitl and Sahl, 2002.

<sup>39</sup> Patton, 1997; Rossi, Freeman, and Lipsey, 1999; Scheirer, 1994.

<sup>40</sup> Lipsey and Cordray, 2000.

Still, synthesizing findings from the few well-designed studies that are available can contribute to a better understanding of 1 to 1 initiatives. Research syntheses can provide policymakers, educators, and researchers with a good idea about what the best evidence is from a range of studies.<sup>41</sup> As scholars who are part of the National Research Council note:

Rarely does one study produce an unequivocal and durable result; multiple methods, applied over time and tied to evidentiary standards, are essential to establishing a base of scientific knowledge. Formal syntheses of research findings across studies are often necessary to discover, test, and explain the diversity of findings that characterize many fields.<sup>42</sup>

### Details of Program Features Are Critical to Strength of Future Studies

#### **Checklist for Evaluation Research Studies of 1 to 1 Initiatives**

- *Clearly state goals of the program and measures used by the program and evaluation to judge success.*
- *Describe the hardware and software that were available for student use and in what settings (for example, at both school and at home).*
- *Describe available technical support and reliability of computers and the network.*
- *Provide details about the content and duration of professional development experiences.*
- *Indicate how mature the 1 to 1 program was at the time of the study.*

Research studies included in this synthesis varied with respect to how much detail they provided about the programs they studied. Nearly all of them reported whether the programs were being implemented at the elementary, middle, or high school level. Most researchers also reported on the demographic characteristics of students in participating schools or districts. However, a number did not clearly specify the overall goals of the initiative they were studying.<sup>43</sup> Many of the programs had multiple goals, but the outcomes measured did not necessarily reflect the goals of program designers.<sup>44</sup> In addition, a number of studies were unclear about the hardware and software used by students in the program<sup>45</sup> and provided little detail on the professional development available to teachers or technical support available to schools.<sup>46</sup> Finally, some researchers did not indicate when in the development of the program they conducted their study, making it difficult to know whether some of the implementation findings are primarily an artifact of a program's novelty in a school or district.<sup>47</sup>

Including information about each of the above features of particular laptop programs in all studies would make research considerably more useful for policymakers and program developers. Policymakers need such information to establish priorities for external funding opportunities and to give guidance to programs on the ways they ought to structure professional development opportunities for teachers and provide for technical support. Program developers need such information so that they can begin to identify "best practices" to replicate in their own program designs. Most educational technology

<sup>41</sup> Slavin, 1986.

<sup>42</sup> National Research Council, 2002.

<sup>43</sup> See, for example, Trimmel and Bachmann, 2004.

<sup>44</sup> See, for example, Jaillet, 2004.

<sup>45</sup> See, for example, Gaynor and Fraser, 2003.

<sup>46</sup> See, for example, Jeroski, 2003.

<sup>47</sup> See, for example, Kemker and Barron, 2004.

innovations combine social, pedagogical, and technological elements, and program designers must constantly adapt and reconfigure these elements as programs evolve.<sup>48</sup>

Success often depends on program managers having a clear roadmap for how enhancing access will eventually lead to other more ambitious goals such as transforming instruction or improving student learning. As part of a grant from the National Science Foundation, the Ubiquitous Computing Consortium has developed some guidance for the kinds of program features and implementation variables that may be important for 1 to 1 initiatives to analyze.<sup>49</sup> In addition to the program features described in the studies we reviewed, the Consortium's evaluation framework emphasizes the need for researchers to articulate the implementation plan for laptop initiatives. The framework also calls for researchers to examine several aspects of implementation of programs, including what teaching and instruction looks like in laptop classrooms, the roles school leaders play in facilitating and supporting teachers' adoption of laptops in classrooms, and the policies and systems that support or hinder implementation efforts. The framework, available on the Internet ([http://ubiqcomputing.org/eval\\_mat\\_framework.html](http://ubiqcomputing.org/eval_mat_framework.html)), is intended to be a tool that researchers in ubiquitous computing initiatives can use to guide the design of evaluation studies.

### **Strengthening Measurements of Potential Outcomes Will Enhance Future Research**

Several studies that focused more on implementation cited outcomes based on self-report survey data that researchers rarely measured in outcome studies. Half of the studies in this synthesis report positive effects of laptop programs on student motivation or engagement, but just three attempted to measure it in some way other than by a single self-report item.<sup>50</sup> These researchers measured motivation either by observation or by using previously validated survey scales of achievement motivation. The widespread belief that laptop programs improve students' motivation to learn could easily be investigated more systematically in future studies by adopting accepted strategies for measurement. Five separate studies reported improvements to student-teacher relationships associated with participation in laptop programs.<sup>51</sup> None of these studies sought to measure the quality of those relationships using available measures with established reliability, however; a number of such measures exist and have been especially important in documenting effects of social and educational programs.<sup>52</sup>

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<sup>48</sup> Means and Penuel, 2005.

<sup>49</sup> Zucker, 2004.

<sup>50</sup> Lowther and Ross, 2003; Russell, Bebell, and Higgins, 2004; Trimmel and Bachmann, 2004.

<sup>51</sup> Fairman, 2004; Lane, 2003; Lowther, Ross, and Morrison, 2001; Mitchell Institute, 2004; Zucker and McGhee, 2005.

<sup>52</sup> Anderson-Butcher, Newsome, and Ferrari, 2003.

***Up-to-Date Resources: A Potential Benefit that Is Difficult to Measure***

*Several studies have reported that wireless connectivity provides students with up-to-date resources for learning that are not available in textbooks. This quotation from a teacher in the Maine Learning Technology Initiative is typical:*

A textbook, particularly a social studies textbook, becomes obsolete or very dry after a short period of time and because of the world wide web and the wireless access that we have here, it's an almost unlimited amount of resources that we can access. It gives the teacher a lot more flexibility to find things that are relevant, that tie into the curriculum, that tie into the Learning Results, whereas before I felt more constricted in what I could do.<sup>55</sup>

*To date, researchers have not used systematic measures of the quality or age of instructional resources students are using in classrooms in reporting results of 1 to 1 initiatives. Such measures may be difficult to create because it is hard to know what resources individual students are using from the Internet. At the same time, a good measure of resources used could provide research-based evidence of an important benefit of 1 to 1 initiatives.*

Some studies reported that students increased their organizational skills with laptop computers<sup>53</sup> and that students gained access to a wider array of up-to-date educational resources as a result of their participation in laptop programs.<sup>54</sup> Both results seem plausible, since many studies reported that students used laptops most often to take notes, track assignments, and find resources on the Internet. Yet there are not many widely accepted measures of organizational skills or of the breadth and quality of materials students can access in school (whether through laptops or textbooks). Researchers conducting future evaluation studies investigating these potential effects of laptops would have to develop and establish the reliability and validity of such measures as part of their research.

Finally, many laptop programs have as their aim broad goals such as the preparation of students for jobs in the 21st century or helping improve the economic competitiveness of the region.<sup>56</sup> Evaluators sometimes report that students are making progress toward skills that might help prepare them for the complex, technology-dependent jobs of the future, such as the ability to collaborate with others, solve complex problems, and communicate clearly.<sup>57</sup> Many of these outcomes are also difficult to measure, but they may be particularly important to assess because they are a central reason why laptops programs are being so widely implemented at the present time. It may be true that laptop programs are effective in meeting these often reported but rarely measured objectives; further research is necessary on an expanded array of outcomes to determine whether this is so.

The increasing popularity of laptop initiatives with a wide variety of stakeholders in education—policymakers, administrators, teachers, parents, and students—makes the need for sound research-based evidence of effectiveness especially critical at this time. States and district school boards must often choose between funding different compelling kinds of programs for students; data on effectiveness can help inform their decision-making process. Although they are difficult to conduct, a significant number of experimental and quasi-experimental studies are needed if laptop programs are to provide stronger research-based evidence warranting investments in 1 to 1 initiatives.

To summarize the key findings from this synthesis, on the basis of our review of 30 well-designed implementation and outcome studies, we concluded:

- Effecting change in teaching practice depends on professional development and changing some teachers' beliefs about the role of technology and students' capabilities.

<sup>53</sup> Lowther, Ross, and Morrison, 2001; Zucker and McGhee, 2005.

<sup>54</sup> Dinnocenti, 2002; Gaynor and Fraser, 2003; Lowther, Ross, and Morrison, 2001; Mitchell Institute, 2004.

<sup>55</sup> Silvernail and Lane, 2004, p. 16.

<sup>56</sup> Jaillet, 2004; Silvernail and Lane, 2004.

<sup>57</sup> Gaynor and Fraser, 2003; Lowther and Ross, 2003; Trimmel and Bachmann, 2004.

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- Available research-based evidence is generally positive, especially with respect to laptop programs' effects on technology use, technology proficiency, and writing skills.
  - Overall, however, there is limited research-based evidence from rigorously designed experimental or quasi-experimental studies of laptop programs' effectiveness.
  - More quasi-experimental and experimental research is needed that examines both outcomes and implementation if further major investments in 1 to 1 initiatives are to be warranted by the research base.

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## Glossary: Key Research Terms Used in this Synthesis

**Outcome studies:** Studies that use objective measures of program impact and that rely on treatment-comparison group designs. Such studies yield research-based evidence about the effectiveness of 1 to 1 initiatives.

**Research-based evidence:** Data gathered from rigorously-designed outcome studies. The strength of research-based evidence depends upon the strength of the research design, not how big the reported effects are.

**Implementation studies:** Studies that use surveys, interviews, or case studies to describe how 1 to 1 programs unfold and how program stakeholders such as parents, teachers, administrators, and students perceive them.

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## Appendix A: Approach to the Research Synthesis

### Scope of the Synthesis

The scope of this synthesis was limited to 1 to 1 initiatives that used laptop computers with wireless connectivity in K-12 education. We included in our synthesis articles that systematically investigated the implementation of laptop initiatives and/or studied outcomes of laptop initiatives using comparison group designs.

### Process for Finding and Selecting Articles

We searched English-language peer-reviewed journals, dissertation abstracts, and the web for studies that might be included in the synthesis using a common set of key words. Initially, our search included 1 to 1 initiatives that used handheld computers or graphing calculators. Researchers at SRI downloaded abstracts from all reports or articles found into End Note.

The initial search yielded 245 articles, of which there were 177 unique articles. Initially, secondary reports of research (such as are found in magazines like *Technology and Learning*), meta-analyses, research syntheses, policy documents, curriculum guides and conference reports were all eliminated from the pool of potential articles for inclusion in the study. After eliminating these, 123 articles remained in the database. Next, we eliminated articles that were outside the intended focus of the study, as evidenced by the study abstracts. A total of 68 articles were eliminated at this point, resulting in 55 articles. Finally, we eliminated articles about handhelds or graphing calculators that were not wirelessly connected, resulting in 46 articles.

We obtained each of these articles, and researchers produced two to three page summaries of key aspects of each study: the goals and design of the 1 to 1 initiative, nature of the technology used, characteristics of schools in the study, data on implementation, and data on outcomes. A more thorough reading of articles and a subsequent decision to restrict the scope of the synthesis to 1 to 1 initiatives using laptops with wireless connectivity led us to include a total of 30 articles in the synthesis.

### Criteria for Inclusion

We included articles in the synthesis that used systematic methods for investigating implementation or outcomes. We applied different criteria for studies we characterize as implementation studies and those we describe as outcome studies.

Outcome studies, to be included, must have employed experimental designs with random assignment or quasi-experimental designs with pre- and post-test data on both treatment and control groups.

Implementation studies, to be included, must have employed systematic methods of analysis of implementation data. Examples include statistical analysis of survey data, grounded theory, comparative case study analysis, or ethnographic analysis.

### Process for Synthesizing Results

Two SRI team members worked independently to review the two to three page summaries and identify a set of recurring themes to highlight in the synthesis. We each worked independently to code individual articles using a spreadsheet to record results of our coding by study. We then reviewed and discussed discrepancies on coding, to agree upon a final code for each study.

## Appendix B: Studies Included in the Synthesis

### Implementation Studies

- Daitzman, P. (2003). *Evaluation of the National Model Laptop Program Technology Literacy: A journey into the global learning community*. New Haven, CT: East Rock Global Magnet School.
- Davies, A. (2004). *Finding proof of learning in a one-to-one computing classroom*. Courtenay, B.C.: Connections Publishing.
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## Outcome Studies

- Gulek, J. C., & Demirtas, H. (2005). Learning with technology: The impact of laptop use on student achievement. *Journal of Technology, Learning, and Assessment*, 3(2).
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